

Full Length Research Paper

Research of some physicochemical and biological pollution indicators in four fisheries of the Northern part of Cameroon

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Abstract

The bacteriological and physicochemical characteristics of water and sediment collected in four fisheries situated in the north of Cameroon were evaluated. In these locations, all the analysed parameters (temperature, pH, salinity, conductivity, turbidity, suspended matter, organic matter, phosphates, sulphates, nitrates, chloride, calcium, magnesium, iron and nitrogen) were the highest, except for chlorides. Total mesophile aerobic flora varied between $1.4 \pm 0.50 \times 10^5$ in Tibati and $5.57 \pm 0.50 \times 10^6$ CFU/mL in Lagdo. *Salmonella* concentration was comprised between 66.66 ± 1.62 in Tibati and 274 ± 3.16 CFU/mL in Yagoua. There was about 10 ± 0.50 CFU/mL *Vibrio* in Lagdo and 342.27 ± 5.53 CFU/mL in Maga. *Staphylococcus* concentration was between $1.4 \pm 0.55 \times 10^3$ CFU/mL in Tibati and $4.44 \pm 0.9 \times 10^4$ in Maga. *Clostridia* were comprised between 0.33 ± 0.00 in Tibati and 226.66 ± 4.29 CFU/mL in Maga while *Pseudomonas* concentration was comprised between 16.26 ± 0.70 in Tibati and 326.66 ± 6.00 CFU/mL in Lagdo. Faecal *Streptococcus* varied between 0.33 ± 0.00 in Tibati and 238.66 ± 8.15 CFU/mL in Yagoua. The total mesophile aerobic flora was significantly high ($P < 0.005$) in Lagdo while *Clostridium*, faecal *streptococcus*, and *Streptococcus* concentration were significantly high in Maga, Yagoua and Lagdo. Lake's sediments in Maga were the most infected. The different analysis revealed that the fisheries were relatively polluted. Some of the bacteria counted like *Pseudomonas* and *Vibrio* might be pathogenic for fishes.

Keywords: Water, sediment, North-Cameroon, microbial quality, physicochemical characteristics.

INTRODUCTION

Water is an essential substance for human beings, animal and plants. In Cameroon, continental waters are estimated for about 35 000 km² at their annual means

List of Abbreviations

FAO; Food and Agriculture Organization, TCBS; Thiosulfate, Citrate, Bile, Sucrose Agar, XLD; Xylose Lysine Deoxycholate, PCA; Plate Count Agar, TSN; Tryptone Sulfite Neomycin Agar, CFU; Colony forming units, IUT; Institut Universitaire de Technologie.

level. These surface waters, principally those of lakes and rivers are of great importance in riparian population's life because of their utilization as in household task, irrigation, bathe, cooking etc. In addition, many fish species grow in these surfaces, among them there are: *Tilapia sp.*, *Lates niloticus*, *Clarias lazera*, *Clarias anguillaris*, *Heterobranchus*, *Auchenoglanis*, *Labeo coubie*, *Mormyrus rhume*, *Hemichromis fasciatus*, *Mormirops*, *Alestes marolepidodus*, *Hydrocynus synodontis*, *Auchenoglanis*, *Hemichromis fasciatus* etc. (Titsop et al., 2003).

However, the hygienic quality of surface waters is thus not always maintained among time. Many African countries have registered these last years a tremendous demographic growth accompanied by a sudden acceleration of urbanization and the land use for industrialization and agriculture purpose. All this increased rejection of various pollutants in surface waters (Saad et al., 1994). Many germs like bacteria, virus and protists are then spread in nature. Water contamination by pathogen microorganisms is able to cause isolated cases of gastroenteritis in humans and even an epidemic situation. Water becomes therefore a privileged transmission vector of these diseases which are the cause of high population mortality.

Water quality, temperature and climatic conditions are among the factors which could influence the constitution of microbial communities in an environment. Pollution resulting from galloping demography affects not only humans but also aquatic wildlife because water quality is the key factor which can finally secure or contrarily affect the survival of aquatic organisms like fish (Mulder, 1986). Fishes are so particularly sensible to aquatic environment quality in which they live and from which they undergo directly all kind of variations (Jallabert et al., 2000). De Sousa (2001) has also shown that a link existed between bacterial communities of water and the fish commensal flora. Many factors influence permanent bacterial community establishment in fishes. Among them there are fish farming environment (Guiraud et Galzy, 1980); water quality (Huss, 1999); water salinity (Sakata et al., 1984) and antibiotics (Pothulvri et al., 1998).

Fish is very important for food security in Cameroon and according to the FAO estimations, it provide for about 40% of animal protein supply (Sheves et al., 1992). It is thus important to determine the pollution degree of some lakes, rivers and dams in which many species of fish grow.

The aim of this study is to evaluate the quality of water and sediments of four fisheries in the northern part of Cameroon: Maga Lake, Lagdo dam, Logone River (Yagoua) and Mbakaou dam (Tibati). Specifically, some physicochemical characteristics like temperature, pH, salinity, conductivity, turbidity, suspended matter, organic matter, phosphates, sulphates, nitrates, chloride, calcium, magnesium, iron and ammoniacal nitrogen were evaluated in water and some microorganism indicators of pollution were count from samples of sediments and water.

MATERIAL AND METHODS

Sampling sites

The choice of these locations in the northern part of Cameroon was guided by the fact that these fisheries contains for about 70% of the national production of fish

in continental waters (Sheves et al., 1992) and a current study on traceability of Tilapia (*Oreochromis niloticus*) of Cameroon is conducted.

- Mbakaou dam (Tibati): Mbakaou dam was constructed on the Djerem River at 2500m of downstream on the swelling scale. It enables to put in reserve 2.5 thousand Millions metre cube of water with a maximum of 846 (Cherrou et Belal, 2005). The main activities around this dam remain fishing with a production of 4000 tons. The main species fished are *Tilapia niloticus*, *Lates niloticus*, *Clarias*, *Auchenoglamis*, *Hydrocynus*, *Alestes macrolepidodus*, *Lobe coubie*, *Mormyride* and *Synodontis*.

- Lagdo dam: Built on the river Benoue, this dam was created to generate hydro-electric energy and agriculture production. In addition this structure has an important function in developing aquaculture activities (Bulckaen, 1992). In this dam, 90% of fishes are represented by six different groups (Toumba, 2000): *tilapia* (55%), *Chrysichrthys* (21%), *Brycinus* (4%), *Cirrhinus* (4%), *Hydrocynus* (3%) and *Lates* (3%). Annual production is nowadays situated around 6000 tons.

- Maga lake: The lake of Maga is an irrigation dam. The length of the dyke is about 28km with a surface of 90km² (May-June) and 360km² (September-November). The fishing activity is very developed around this lake shared by 35 villages and fishing camps. Annual production is estimated between 2000 and 3000 tons and the main species found are *Tilapia*, *Bagrus*, *Alestes*, *Heterotis*, *Gymnarchus*, *Labeo*, *Lates*, *Citharinus*, *Distichodus*, *Mormirus*, *Sydontis*, *Auchenoglanus*, *Hydrocynus* and *Tetradon*.

Water and sediment sampling

Water and sediment samples were collected in rainy season (July 2008) from Logone river in Yagoua (Far north region); in the artificial lake of Maga (Far north region); in hydro-electric dams of Lagdo (North region) and Mbakaou in Tibati (Adamawa region) (Figure 1). 500mL of water were collected in sterile polyethylene bottles at a depth comprise between 15 and 20 cm of the surface water. For each location, three surface water samples were collected distanced from each other with at least 200 m. Sediments were also collected in three different places in sterile flasks of 100 mL. The samples were transported to the laboratory in cool box (+4 °C).

Analysis

Physicochemical analysis of water

Temperature (°C) and pH were measured *in situ* using a Universal pocket pH-meter (Hanna HI 8424). Different values were measured after electrode immersion in water

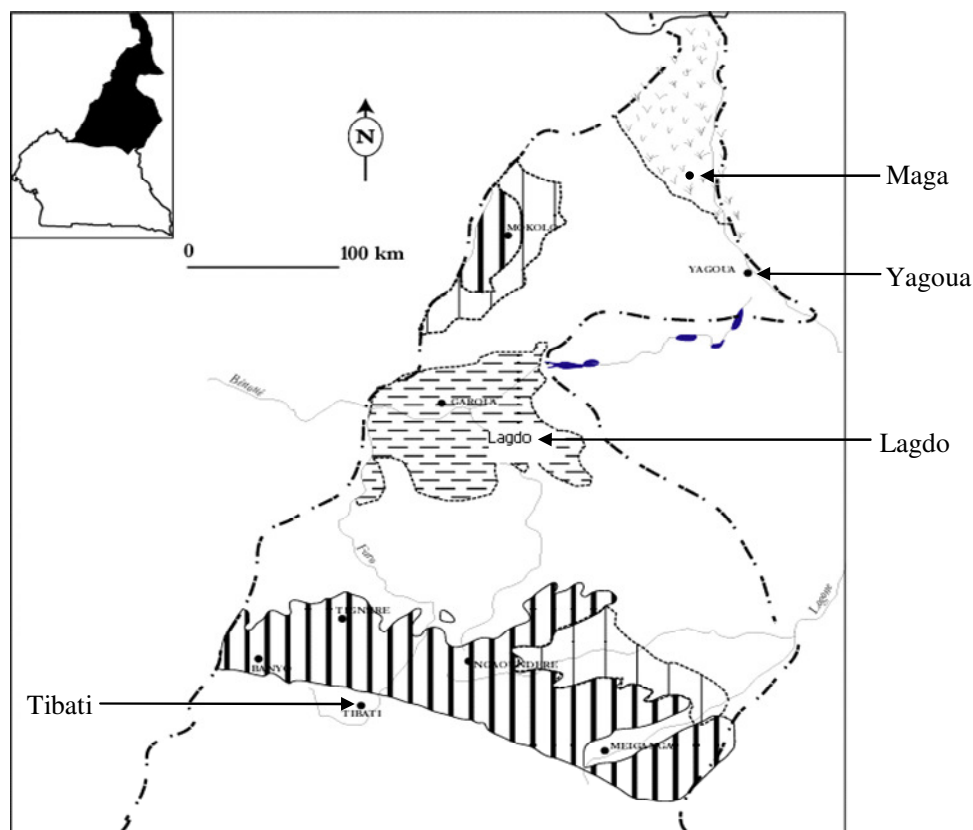


Figure 1. Sampling locations : Maga, Yagoua, Lagdo and Tibati

for about 7 min (Rodier, 1978). Conductivity ($\mu\text{S}/\text{cm}$) and salinity were also measured *in situ* with a portable conductimeter (Hanna Instrument HI 8033) by immersing electrodes directly in the samples (Rodier, 1978). Other elements of water samples were measured in laboratory: suspended mater (mg/L) by a method described by Bouquiaux et al. (1953); turbidity (NTU) determined by visual method (OMM, 1988); calcium (mg/L), magnesium, chloride (mg/L), organic matter ($\text{mg O}_2/\text{L}$), nitrates (mg/L), sulphates (mg/L), dissolved iron (mg/L), phosphates (mg/L) and ammoniacal nitrogen (mg/L) determined by a method described by Rodier (1978).

Microbial examination of water and sediment samples

Water

Samples dilutions were made (10^{-1} - 10^{-6}) with sterile physiological saline solution (0.85% w/v NaCl). 100 μL of the serial dilution were plated ($\varnothing=20\text{cm}$) onto TCBS (Thiosulfate, Citrate, Bile, Sucrose Agar) for vibrio isolation, XLD (xylose lysine deoxycholate) for the isolation of *Salmonella* and *Shigella*, PCA (Plate Count Agar) for isolation of the total flora, Baird Parker for

isolation of *Staphylococcus aureus*, Cetrimide agar base for *Pseudomonas aeruginosa* isolation. All the inoculated plates were incubated at 37°C for 24-48h.

For *Enterococcus* and faecal *Streptococcus* isolation, 100 mL of sample were filtered under vacuum packed condition. The filtration membrane was taken aseptically and laid down on Petri dishes containing Slanetz and Bartley agar and incubated at 44°C for 24-48h.

TSN (Tryptone Sulfite Neomycin agar) was used to detect *Clostridium perfringens* in water samples. 1 mL of sample was warmed at 80°C for 10 min. After cooling, 9 mL of TSN was then added to the sample.

Colony forming units (CFU) were counted with a Quebec Darkfield Colony Counter (Leica, Inc., Buffalo, New York) equipped with a guide plate ruled in square centimetres. Plates having ≥ 1 to 300 colonies were used to calculate bacterial population results, recorded as CFU per mL. Each count was the mean value of viable colonies appearing in duplicate agar plates made per individual sample.

Sediments

Twenty grams of sediments were added aseptically to 180 mL of sterile physiological saline solution (0.85% w/v

Table 1. Physicochemical parameters of samples collected from Tibati, Yagoua, Lagdo and Tibati

Parameters	Locations			
	Tibati	Yagoua	Maga	Lagdo
Temperature (°C)	27.86±0.6 ^a	30.54±0.44 ^{bc}	32.32±1.0 ^c	29.38±0.16 ^{ab}
pH	6.36±0.08 ^a	7.77±0.15 ^b	7.65±0.13 ^b	7.71±0.14 ^b
Salinity (ppm CaCO ₃)	0.03±0.00 ^a	0.11±0.00 ^b	0.57±0.02 ^d	0.24±0.02 ^c
Conductivity (µS/cm)	27.05±0.96 ^a	178±2.29 ^b	849.22±3.71 ^d	297.00±3.46 ^c
Turbidity (NTU)	5.8±0.5 ^a	396.67±1.00 ^c	209.53±1.40 ^b	39.77±0.79 ^a
Suspended matter (mg/l)	0.60±0.07 ^a	1.30±0 ^b	1.17±0.06 ^b	0.70±0.00 ^a
Organic matter (mgO ₂ /l)	4.67±0.53 ^a	14.67±0.02 ^c	7.33±0.57 ^b	13.0±0.10 ^c
Phosphates (mg/l)	3.05±0.03 ^a	6.60±0.61 ^c	5.68±0.22 ^b	3.42±0.09 ^a
Sulphates (mg/l)	0.65±0 ^a	2.14±0.29 ^c	0.94±0.05 ^b	0.95±0.01 ^b
Nitrate (mg/l)	0.26±0.05 ^b	0.50±0.06 ^c	0.36±0.02 ^{bc}	0.05±0.00 ^a
Chloride (mg/l)	47.33±0.02 ^c	39.05±0.15 ^a	44.97±0.02 ^b	46.74±0.05 ^{bc}
Calcium (mg/l)	13.33±0.15 ^a	12.67±1.15 ^a	16.67±1 ^b	11.33±0.11 ^a
Magnesium (mg/l)	12±0.21 ^b	12±0.12 ^b	16.80±0.2 ^c	9.60±0.05 ^a
Iron (mg/l)	0.5±0.04 ^a	1.93±0.87 ^b	1.43±0.41 ^b	0.38±0.08 ^a
Ammoniacal nitrogen (mg/l)	0.78±0.02 ^a	2.6±0.6 ^b	2.74±0.16 ^b	1.81±0.26 ^b

The values with the same letter are significantly different (P<0.05)

NaCl) and mixed. 1 mL of each sample was diluted (10^{-1} - 10^{-10}) and plated like water samples.

Statistical analysis of variances was performed on Statgraphics plus 5.0 software followed by Duncan test. Principal component analysis (PCA) and K-means classification were also performed with XLSTAT (Addingsoft) software version 2010.2.03

RESULTS

Physicochemical characteristics

Many parameters influence water quality. Results obtained on physicochemical parameters were the mean of three replicates (Table 1). The water temperatures were comprise between 27.8±0.6°C (Tibati) and 32.3±1.0°C (Maga) while pH were between 6.36±0.08 (Tibati) and 7.77±0.15 (Yagoua). Salinity was between 0.03±0.00 ppm CaCO₃ (Tibati) and 0.57±0.02 ppm CaCO₃ (Maga). The water conductivity was comprised between 27.05±0.96 µS/cm (Tibati) and 849.22±3.71 µS/cm (Maga), while turbidity was between 5.8±0.5 NTU (Tibati) and 396.7±1.00 NTU (Yagoua). Suspended matters varied between 0.60±0.07 mg/L (Tibati) and 1.30±0 mg/L (Yagoua) while Organic matters were between 4.67±0.53 mg O₂/L (Tibati) and 14.67±0.02 mg O₂/L (Yagoua).

Phosphates were comprised between 3.05±0.03 mg/L (Tibati) and 6.60±0.61 mg/L (Yagoua) while Sulphates between 0.65±0 mg/L (Tibati) and 2.14±0.29 mg/L

(Yagoua). The water samples contained between 0.05±0.00 mg/L (Lagdo) and 0.50±0.06 mg/L (Yagoua) Nitrates while Chloride content was between 39.05±0.15 mg/L (Yagoua) and 47.33±0.12 mg/L (Tibati). The samples contained between 11.33±0.15 mg/L (Lagdo) and 16.67±1 mg/L (Maga) of calcium while magnesium content was between 9.60±0 mg/L (Lagdo) and 16.80±0.2 mg/L (Maga). Iron content was comprise between 0.38±0.08 mg/L (Lagdo) and 1.93±0.07 mg/L (Yagoua), the nitrogen content was between 0.78±0.02 mg/L (Tibati) and 2.74±0.16 mg/L (Maga). For all the measured parameters, the differences between the means were significative.

A Principal component analysis (PCA) study was performed between the physico-chemical and bacterial characteristic of water. This analysis shown that in the samples of Maga, elements like Calcium, Magnesium and Nitrogen were more concentrated. Parameters like conductivity, temperature and salinity were higher. On the other side, in the samples of Yagoua: iron, phosphates, nitrates, sulphates, organic matter and suspended matter were more concentrated. Turbidity was also higher in the samples of Yagoua. Chlorides were more concentrated in the samples of Lagdo. This analysis showed also that the samples of water collected on the same location had the same characteristics and they were closer (Figure 2B). The samples of Yagoua were closer to those of Maga. The K-means classification showed that there were four classes and Yagoua was classified as the location with highest parameters.

Table 2. Microbial counting from water from 4 locations

Microorganisms	Locations			
	Tibati	Yagoua	Maga	Lagdo
Total Flora (CFU/mL)	$1.46 \pm 0.5 \times 10^{5a}$	$1.8 \pm 0.52 \times 10^{6a}$	$1.6 \pm 0.7 \times 10^{6a}$	$5.57 \pm 0.47 \times 10^{6b}$
<i>Salmonella</i> (CFU/mL)	66.66 ± 1.62^a	274 ± 3.16^a	185.16 ± 9.14^a	182 ± 1.37^a
<i>Vibrio</i> (CFU/mL)	14 ± 0.60^a	133.33 ± 7.73^a	342.27 ± 5.53^a	10 ± 0.5^a
<i>Staphylococcus</i> (CFU/mL)	$1.4 \pm 0.55 \times 10^{3a}$	$2.11 \pm 0.11 \times 10^{4a}$	$4.44 \pm 0.9 \times 10^{4a}$	$2.36 \pm 0.55 \times 10^{4a}$
<i>Clostridium</i> (CFU/mL)	0.33 ± 0.00^a	19 ± 0.58^a	226.66 ± 4.29^b	201.66 ± 7.68^b
Faecal <i>Streptococcus</i> (CFU/100mL)	0.33 ± 0.00^a	238.66 ± 8.15^b	31 ± 0.64^a	46.33 ± 0.02^a
<i>Pseudomonas</i> (CFU /100mL)	16.26 ± 0.17^a	130 ± 6.45^b	266.66 ± 7.73^c	326.66 ± 6^c

The values with the same letter are significantly different ($P < 0.05$)

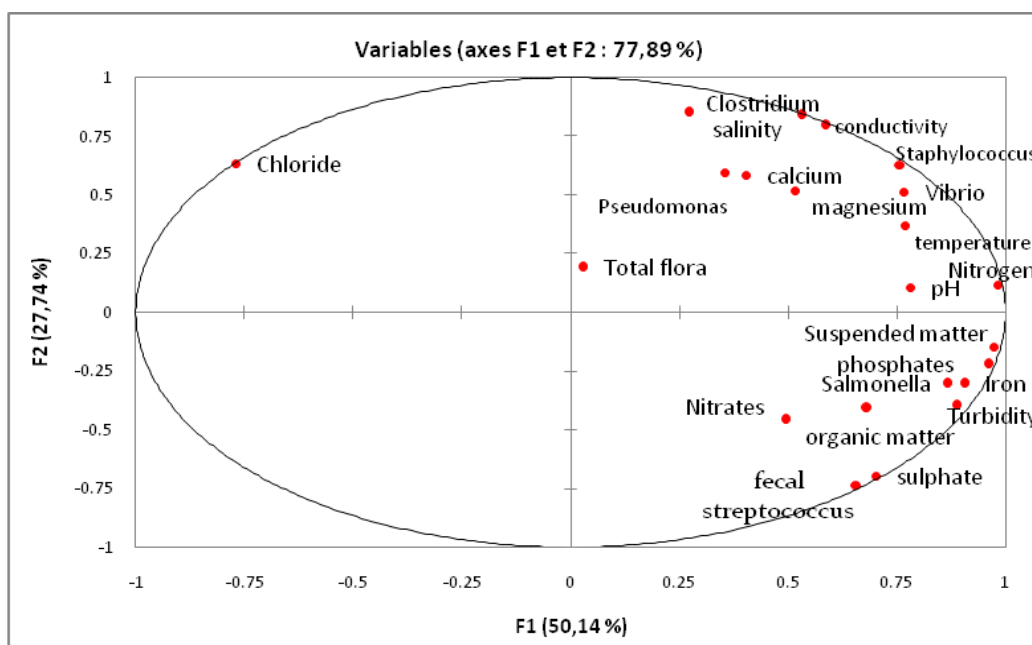


Figure 2A. Principal component analysis: Correlation circle between physicochemical parameters of water and bacterial concentration of water samples collected in Maga, Yagoua, Lagdo and Tibati.

Microbial flora of water samples

After bacterial growth on specific media, Colonies Forming Units (CFU) was counted (Table 2). The total flora obtained was between $1.46 \pm 0.5 \times 10^5$ (Tibati) and $5.57 \pm 0.5 \times 10^6$ CFU/mL (Lagdo) while the amount of *Salmonella* was between 66.66 ± 1.62 (Tibati) and 274 ± 3.16 CFU /mL (Yagoua). The number of *Vibrio* colonies was between 10 ± 0.5 (Lagdo) and 342.27 ± 5.53 CFU/mL (Maga) while *Staphylococcus* were between $1.4 \pm 0.55 \times 10^3$ (Tibati) and $4.44 \pm 0.9 \times 10^{4a}$ CFU/mL (Maga). *Clostridium* number was between 0.33 ± 0.00 (Tibati) and 226.66 ± 4.29 CFU/mL (Maga), while 0.33 ± 0.00 (Tibati) to 238.66 ± 8.15 CFU/mL (Yagoua) faecal *Streptococcus* were counted. There were

16.26 ± 0.17 (Tibati) to 326.66 ± 6 CFU/mL (Lagdo) *Pseudomonas*. A significative (at 5% level) difference was observed between the means of bacterial concentration from different location except for *Salmonella*, *Staphylococcus* and *Vibrio*.

The circle of correlation (figure 2A) obtained after PCA analysis revealed that a positive correlation exists between microorganisms like *Salmonella* and faecal *Streptococcus*. These microorganisms were more concentrated in the samples of yagoua (Figure 2B) and were positively correlated to physicochemical parameters such as: sulphates, organic matter, turbidity, iron, phosphates, nitrates pH, suspended matter and nitrogen. In The samples of Maga, the parameters like temperature, magnesium, calcium, conductivity, salinity

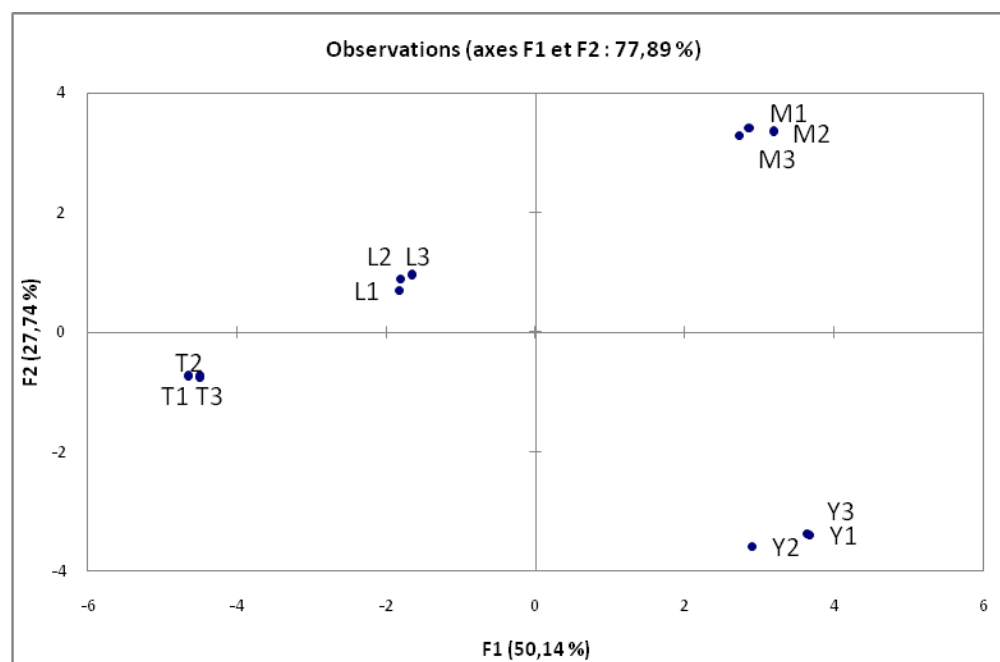


Figure 2B. Principal component analysis: Representation of individuals and variables in the factorial space between physicochemical parameters of water and bacterial concentration of water samples collected in Maga (M1: up stream, M2: middle and M3: downstream) Yagoua (Y1: up stream, Y2: middle and Y3: downstream), Lagdo (L1: up stream, L2: middle and L3: downstream) and Tibati T1: up stream, T2: middle and T3: downstream).

were positively correlated to *Staphylococcus*, *Clostridium*, *Pseudomonas*, total flora and *Vibrio*.

Microbial flora of sediments samples

The count of bacteria revealed that the total flora obtained was between $16.0 \pm 3 \times 10^7$ (Tibati) and $2.07 \pm 0.06 \times 10^{10}$ CFU/g (Maga) while *Salmonella* were between 983.33 ± 2.46 (Tibati) and $1.13 \pm 0.01 \times 10^5$ CFU/g (Yagoua). The number of *Vibrio* colonies was between 616.66 ± 5.83 (Tibati) and $6.2 \pm 0.8 \times 10^4$ CFU/g (Maga) while *Staphylococcus* were between $1.16 \pm 0.03 \times 10^3$ (Tibati) and $9.0 \pm 0.05 \times 10^4$ CFU/g (Lagdo) *Clostridium* number was between 22.33 ± 0.23 (Tibati) and 506.66 ± 0.41 CFU/g (Maga) while faecal *Streptococcus* were between 13.33 ± 0.27 (Maga) and 23.33 ± 0.77 CFU/g (Yagoua). There were 3.66 ± 0.78 (Tibati) to 140 ± 1 CFU/g (Maga) *Pseudomonas*. The differences were significant between the means of all the bacterial concentration analysed except for faecal *Streptococcus*. The relationship between physicochemical parameters of water and the microbial flora of sediments was established with Principal Component Analysis (Figure 3). This analysis showed in figure 3A that *Vibrio*, *Pseudomonas*, *Staphylococcus* and *Clostridium* were more concentrated and positively correlated to physicochemical parameters like temperature,

magnesium, calcium, conductivity and salinity. These four types of bacteria were more abundant in the samples of Maga (figure 3B). In the samples of Yagoua, bacteria like *Salmonella* and total aerobic mesophilic flora were more concentrated. These two types of microorganisms were positively and significantly (at 5% level) correlated to physicochemical parameters like organic matter, turbidity, nitrates, iron, phosphates, suspended matter, sulphates, nitrogen and pH. The K-means classification showed that the samples of Maga and Yagoua were closer.

DISCUSSION

The measured temperatures correspond to ambient atmospheric temperature. In Maga, Yagoua and Lagdo, temperatures were higher than in the samples of Tibati because they are situated in the hottest part of the country where the atmospheric temperature could rise to more than 45°C in the shade. The highest temperature ($32.32 \pm 1.0^\circ\text{C}$) was measured in Maga. This could be a result of intense human activity around the lake. These human activities produce organic waste which could be decomposed and increase temperature. The waters of different locations were basic except for the samples collected in Tibati which were slightly acid. This difference in pH could also be linked to the type of soil and microbial activity. Proteins degradation could

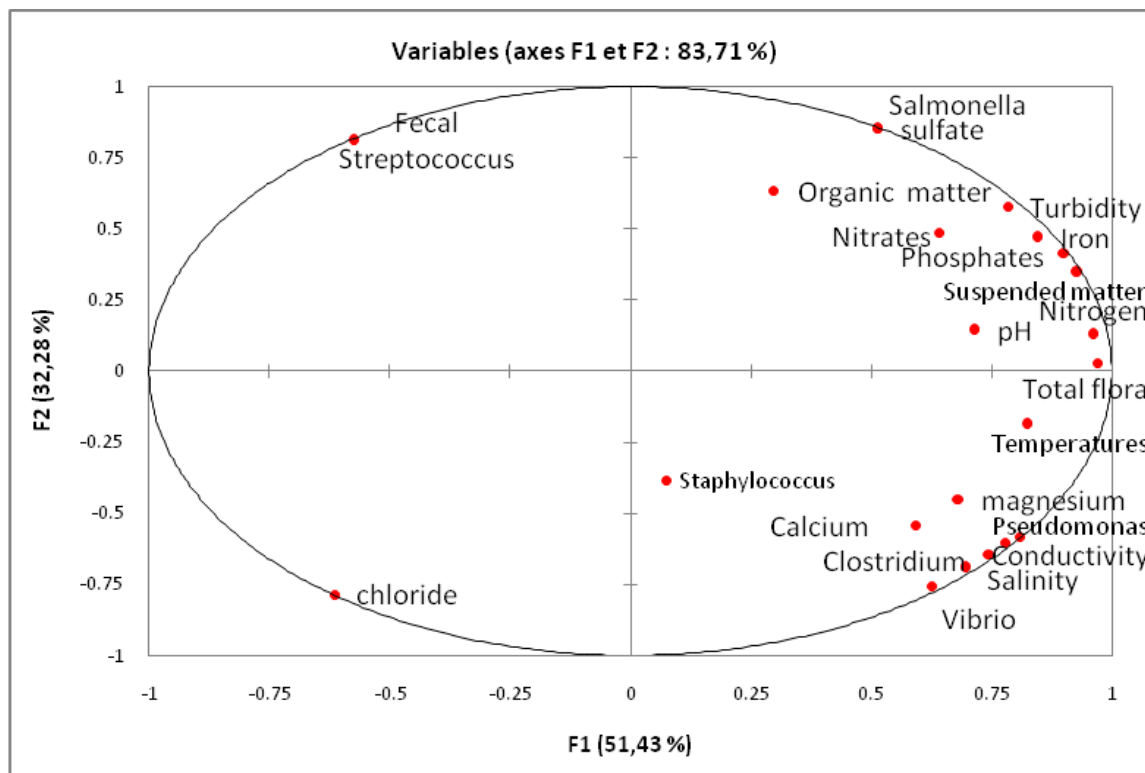


Figure 3A. Principal component analysis: Correlation circle between physicochemical parameters of water and bacterial concentration of sediment samples collected in Mago, Yagoua, Lagdo and Tibati.

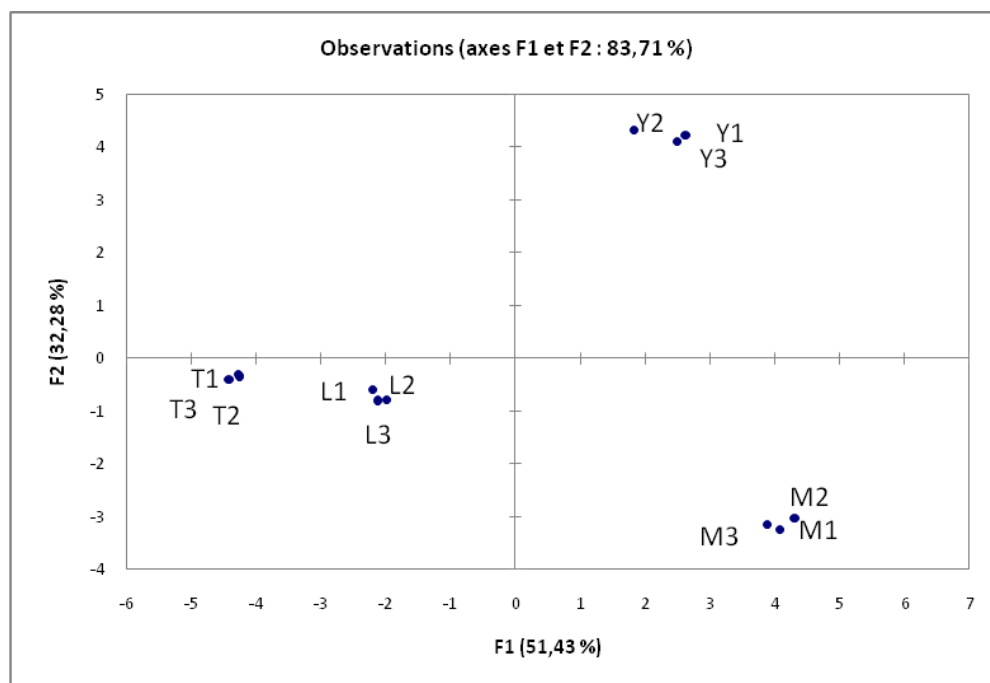


Figure 3B. Principal component analysis: Representation of individuals and variables in the factorial space between physicochemical parameters of water and bacterial concentration of sediment samples collected in Mago (M1: up stream, M2: middle and M3: downstream) Yagoua (Y1: up stream, Y2: middle and Y3: downstream), Lagdo (L1: up stream, L2: middle and L3: downstream) and Tibati T1: up stream, T2: middle and T3: downstream).

produce basic molecules. Turbidity is correlated to suspended matter. Increased turbidity could be due to heavy rains fall that carry away clay, silt and fragment of litter in water. This also could be due to human activity around the lake. Turbidity in the samples of Maga and Yagoua were higher than the maximum limit fixed by Canadian norm (80 NTU). Salinity (increased in Maga with 0.57 ± 0.02 ppm CaCO_3) chloride and sulphate concentrations could be influenced both by the geologic structure of the sector (James et Evison, 1979) and the sampling period (Rodier, 1978; Aguiza, 2007). The lower concentrations in nitrate could be due to denitrification caused by increased number of denitrifying bacteria (Grouhel et al., 1995). The results obtained in our study were lower than those obtained by Aguiza (2007) in surface water collected in Ngaoundere (Cameroon), but they were in agreement with those recommended by AFNOR on surface waters which must be lower to 10.0 mg/L.

The iron concentration content was higher in Yagoua and Maga samples due probably to soil constitution and heavy rain fall (Tchotsoua et al., 1998). Calcium and magnesium concentrations obtained were closer to those obtained by Aguiza (2007). This author analysed the samples collected from some rivers in Ngaoundere town (Cameroon), he found that the mean concentration of calcium was 14.11 mg/L while the magnesium content was 14.14 mg/L. The water concentration in phosphates, organic matters, ammoniacal nitrogen was high in Yagoua samples. This could be due to human activities around the river Logone. Moreover, with rainy season, dirty water is drained into rivers inducing the washing of cultivated soil where fertilizers have been used (Rodier, 1978; Bergen et al., 1992; Doriez et al., 1997; Hupfer et Steinberg, 1997).

The microbial analysis of water and sediments revealed the presence of pathogenic microorganisms (for man and animals) like *Salmonella* and *Shigella*, *Vibrio*, *Clostridium perfringens*, *Pseudomonas*, faecal *Streptococci* and *Staphylococcus*. All these bacteria were found in different amount in the four locations. Their presence in water and sediment might be due to their exposure to pollution elements like organic matter, suspended matter, human and animal's excrements. These elements increase the growth of microorganisms, seaweeds and fungi in water (Rodier, 1978; Ashbolt, 2004).

Microorganisms were more concentrated in Maga sediment samples. This might be due to the fact that fishermen mix clay with cereals bran to trap fishes in the lake. As a result of this practice, there is lake depth reduction and its enrichment with organic matter and consequently with microorganisms.

A comparison between the physicochemical characteristics of our samples with some norms (Canadian and AFNOR) showed that turbidity (in Maga

and Yagoua), organic matter (in Yagoua, Maga and Lagdo) and phosphates (in Yagoua, Maga and Lagdo) content of some samples were higher than the concentrations recommended for surface waters. These concentrations could affect aquatic life in general and fishes particularly.

Principal component analysis showed that more physicochemical parameters are high, more abundant were the microorganisms. Besides waters collected from Maga, Yagoua and Lagdo were more polluted probably because of their proximity with numerous villages and their related activities. The consequence of this pollution is the colonization of fish organs (skin, gills and intestines) by microorganisms found in the lake or river (Shewan, 1977). Among the microorganisms found in the water of different locations studied, some like *Vibrio parahaemolyticus* and *Pseudomonas* might be pathogen for fishes. The diseases caused to fishes by these pathogenic microorganisms are economically important but they are of less importance for consumers' health (Toranzo et al., 2003; Toranzo et al., 2005).

The samples of Yagoua were closer to those of Maga. They were closer because of their higher values of physicochemical parameters except for Chloride (Figure 2A). The K-means classification showed that there were four classes and Yagoua was classified as the location with highest parameters. In addition to this, salinity, conductivity, calcium, temperature, pH, Nitrogen, Magnesium favoured the proliferation of some bacteria like: *Clostridium*, *Staphylococcus*, *Vibrio*, *Pseudomonas* in Maga. On the other hand, suspended matter, phosphates, iron, turbidity, organic matter and sulphates enhanced the growth of bacteria such as *Salmonella*, Faecal *Streptococcus* in the samples of Yagoua.

CONCLUSION

The aim of this study was to evaluate the physicochemical and microbiological quality of water and sediment of four locations situated in the northern part of Cameroon. Generally the more contaminated locations were also those with higher physicochemical parameters. The lake of Maga was the most contaminated. This situation could have an impact on the life of aquatic organisms in general and on fishes particularly.

ACKNOWLEDGMENTS

Authors are grateful to all the personnel of the laboratory of Mineral Chemistry of ENSAI (National Advanced School of Agro-Industrial Sciences), and IUT (Institut Universitaire de Technologie) for their help in realising this work.

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